Fluorescence-Doped Particles for Simultaneous Temperature and Velocity Imaging

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Purpose

The purpose of this investigation is to develop, characterize and implement non-toxic micron-sized particles for measurements in wind tunnels that have additional capability beyond the state of the art. Particles are routinely used in wind tunnels for laser Doppler velocimetry (LDV) and particle image velocimetry (PIV) measurements of velocity. With the new approach, we will synthesize particles containing non-toxic dyes and/or paints. The fluorescent particles can be used in a variety of applications: (i) improved signal-to-noise ratio in applications where incident laser light needs to be rejected (e.g. near surfaces), (ii) seeding of fluid streams when two or more fluid streams need to be identified (e.g. in fuel-air mixing), (iii) measurement of temperature, allowing simultaneous temperature and velocity measurements either at a point (LDV) or in a plane (PIV) and possibly (iv) gaseous pressure measurements, simultaneous with velocity.

Background

Characterization of air flow parameters in wind tunnel tests is achieved using a variety of different techniques including particle image velocimetry (PIV) and laser Doppler velocimetry (LDV). For many years, our team has produced polystyrene latex (PSL) microspheres for wind tunnel experiments. Past efforts have focused on improving the control of particle size. The current effort aims to add additional functionality to the PSL microspheres.

Laser dyes have previously been doped into particles used for LDV and PIV for simultaneous measurement of temperature and velocity. However, the laser dyes used were toxic and therefore could not be used in large NASA wind-tunnel facilities. So use of a non-toxic dye would be an enabling advancement. In two-stream flows, fluorescence can be used to distinguish between the fluid streams. These improvements have not been investigated fully. Finally, we plan to investigate the ability to measure velocity, temperature and perhaps pressure simultaneously with particles, possibly by mixing different types of particles in the flow.

If successful, this technology would provide a new method for simultaneously measuring two (possibly three) of the most important parameters in fluid flow: the velocity, temperature (and pressure) fields. These could be used to infer or to better understand heat transfer and skin friction at the wall which will aid in determining boundary layer state for transition and turbulence modeling. Particularly in variable property/compressible turbulent flows, the appearance of scalar-weighted moments, e.g., Favre averaging via fluctuating density, $\overline{\rho' u_i' u_j'}$ or fluctuating temperature flux in the energy equation, $\overline{T' u_i'}$, have presented a major challenge in RANS model validation due to the difficulty in measuring these quantities. Quantitative velocity, temperature (and pressure) data will be used to validate computer codes that are used to design NASA's aircraft. In order ensure that the products of this research will be used, approaches are being investigated which will lead to the new measurement capability being able to be implemented with existing laser and camera technology – the same or similar equipment currently used for LDV and PDV.